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A FAST BREEDER REACTOR SPENT FUEL MEASUREMENTS PROGRAM FOR BN-350 REACTOR

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Abstract
A project to verify the fissile content of fast breeder reactor spent nuclear fuel is underway in the Republic of Kasakhstan. There are a variety of assembly types with different irradiation histories and profiles in the reactor that require a variety of measurement and analysis procedures. These procedures will be discussed and compared as will the general process that has been designed to resolve any potential measurement discrepancies. The underwater counter is part of a system that is designed to assist the International Atomic Energy Agency (IAEA) in maintaining continuity of knowledge from the time of measurement until the measured item is placed in a welded container with a unique identification. In addition to satisfying IAEA requirements for the spent nuclear fuel, this measurement program is able to satisfy some of the measurement requirements for the Kasakhstan Atomic Energy Agency concerning the repackaging of the spent nuclear fuel into a standard canister. The project is currently operational in a mode requiring the IAEA's continuous presence.

INTRODUCTION
An underwater neutron coincidence counter has been designed and installed at the BN-350 reactor in Aktau, Kasakhstan. We have designed the underwater neutron coincidence counter such that it can be used to measure the plutonium content of the spent nuclear fuel discharged from the BN-350 reactor. The International Atomic Energy Agency (IAEA) has designated the official name as the Spent Fuel Coincidence Counter (SFCC). An international safeguards program is presently underway to relocate spent nuclear fuel from the BN-350 fast breeder reactor storage pond in Aqtau, Republic of Kazakhstan. To satisfy IAEA and Kazakhstan Atomic Energy Agency (KAEA) requirements, the plutonium content of these fuel assemblies must be measured prior to their repackaging and relocation. The SFCC is a medium-detection efficiency right-circular cylinder neutron coincidence counter design that incorporates an ionization chamber (IC) for gamma-ray dose evaluation from the spent nuclear fuel. The SFCC is hermetically sealed, as it is installed approximately 5 m below water level in the spent fuel storage pond. Figure 1 shows a cross section of the SFCC, there are 20 ^{3}He tubes arranged within a polyethylene ring. There is an inner ring of 6.8 cm of lead to provide shielding from the fission product gamma rays. A single IC is primarily used to determine the dose impinging upon the ^{3}He tubes and to determine the appropriate high voltage to avoid gamma-ray pile effects in the ^{3}He tubes.

The ^{3}He tubes each had a pressure of 4 atm, a diameter of 2.54 cm, and an active length of 30 cm. The 20 ^{3}He tubes, the ionization chamber, the polyethylene, and the lead shielding were all enclosed within a pressurized stainless steel can with an outer diameter of 50 cm and a height of 60 cm. The diameter of the hole through the middle of the SFCC through which fuel assemblies pass is 15.9 cm. The outer stainless steel can is attached to the surface of the storage pond by a 12-m-long flexible hose. It is through this hose that voltages are fed to, and signals received from, the SFCC. Compressed gas is fed into the umbilical cord to keep the SFCC pressurized at all times.

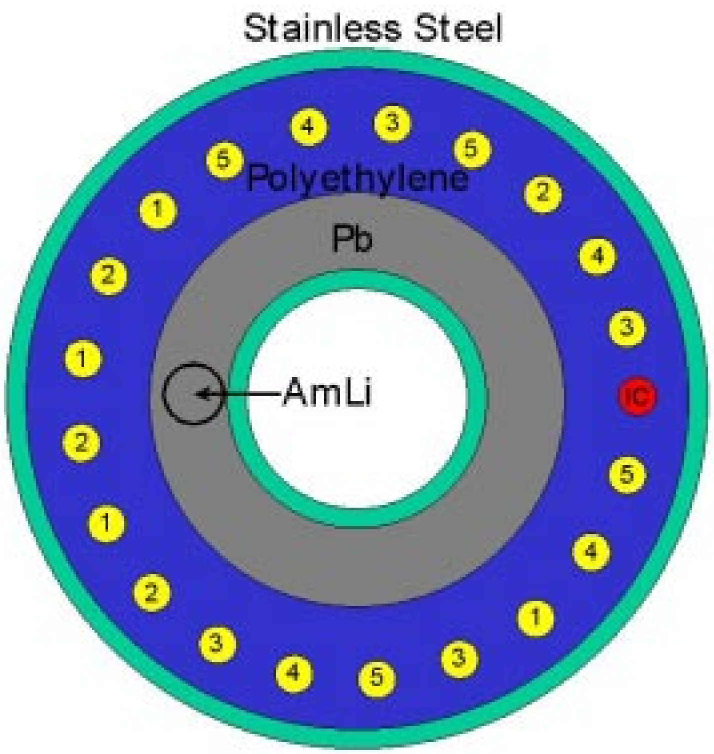

Fig. 1. A cross-sectional slice of the SFCC showing details of the layout of the detectors and shielding materials.

The BN-350 fuel assemblies can be divided into two main types: drivers and blankets. Both of these types have a hexagonal arrangement of fuel pins inside a hexagonal stainless steel shell. This stainless steel shell has a face-to-face distance of 96 mm and a wall thickness of 2 mm. The blanket assemblies contain 37 stainless-steel-cladded depleted uranium pins. The driver assemblies are more complex than the blanket assemblies and are divided into three classes of drivers, types I, II, and III. Each of these types consists of two depleted uranium (blanket) regions situated above and below a central region containing enriched uranium. The blanket regions come in two geometry types: integral and separate. The type I drivers have a separate blanket region both above and below an approximately 1-meter-long 17% or 26% enriched uranium zone. Type II drivers have an integral blanket region above the 17% or 26% enriched uranium zone and a separate blanket region below. Type III drivers have an integral blanket above a 17%, 21%, or 26% enriched uranium zone and an integral blanket below. The different driver assemblies have various pin configurations. In addition to the driver and blanket assemblies, there are two main types of control rods, one that is similar to the standard driver geometry, and the second consists of the upper section containing the blanket pin geometry and the lower section containing the driver pin geometry. Various experimental assembly types are also present and will not be covered further in this document other than to mention that they are typically classified as driver assemblies and measured using the seven point assay position algorithm described later in the document.

The analysis algorithms for the assemblies are separated into four types, with two similar measurement protocols each for blankets and drivers. The first type consists of three measurement points. One measurement point for a determination of the total plutonium content of the assembly based upon a scaling factor determined from Monte Carlo calculations and detailed measurements of a group of assemblies at the beginning of the campaign. The single point used for the measurements is the position considered the axial midplane of the assembly, otherwise known in our nomenclature as the 0-cm position. The other two measurement points of this type analysis are to verify that the distribution of material along the assembly is as expected based upon the ratio of the total neutron count rate at the various positions. The second type consists of seven measurement positions uniformly distributed along the assembly length. Integration is then performed over the measured distribution of the plutonium density to determine the total plutonium content of the assembly. The difference in the assembly type analysis options is primarily dependent upon the varying plutonium isotopics. Further information and details concerning the analysis of the measurement data are available in Reference 1.

There is a measurement protocol in place to resolve measurement discrepancies with the three-position algorithm, this is simply the addition of two supplementary measurement points to verify the distribution of material along the assembly. A reasonable alternative is to apply the seven-position measurement protocol to the failed three-position measurement. In fact, this is the typical anomaly resolution method that has been applied to discrepant measurement results.

There are several options available for the analysis of the measurement results. These options are dependent upon the assembly environment. It is possible to take into account the assembly being placed inside of a stainless steel tube, called an overpack, and then either having argon or water present inside the overpack. It is also possible to scale the measurement results for lower quantities of pins or an extremely different heavy-metal-to-water ratio. Figure 2 shows the input window from the acquisition software where the information for each of the assemblies is entered and the analysis options are selected. The Other (Driver or Blanket) option indicates the users' preference to perform a seven-point measurement.

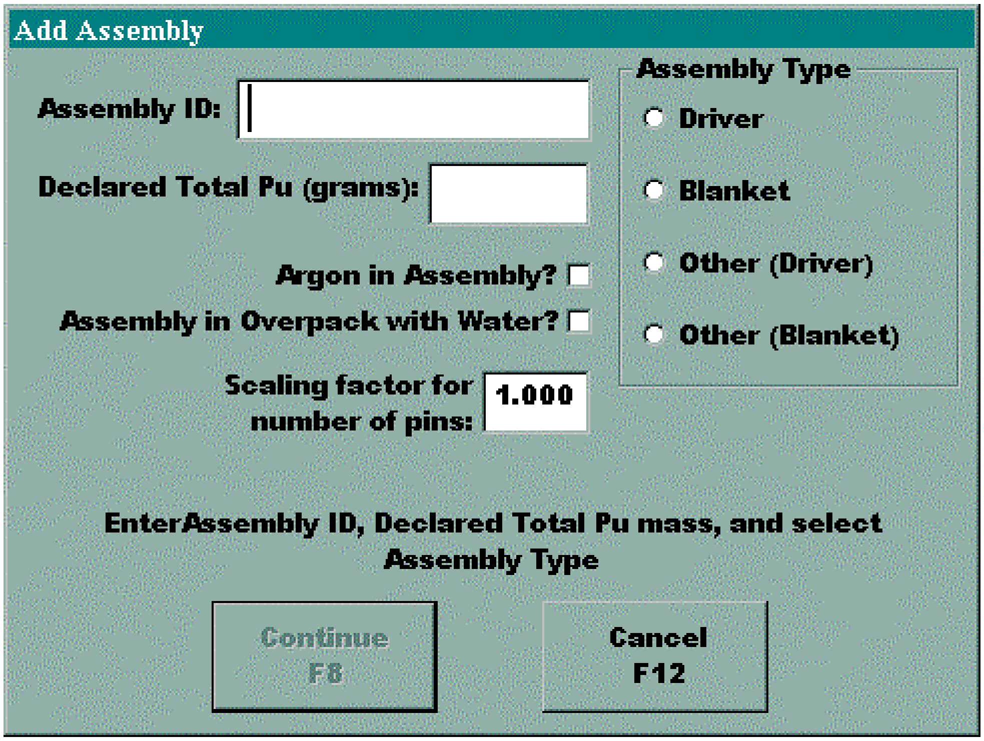

Fig. 2. The data entry window for the acquisition software showing the information and analysis option buttons available for the user to select the type of analysis to be performed on the measurement data.

The general protocol for the measurement of an assembly follows. The identification of the assembly is verified via an underwater camera. This occurs immediately above the SFCC measurement station. After the identification of the assembly is confirmed, the assembly is placed at the appropriate vertical positions dependent upon the analysis option selected. The time for each measurement position is at least 1 min and may be as long as 7 min. These times are adjustable within the software to enable either more rapid measurements to take place or to allow the acquisition of data to occur over longer periods of time to reduce the statistical counting uncertainty. At each of the measurement positions, the IC level is measured via the software and monitored to verify that the gamma-ray dose impinging upon the ^{3}He tubes is below a level at which gamma-ray pile up could affect the neutron measurement results. After each of the required positions have been measured the results are compared with declared values and if the results are within an acceptable range the assembly is placed into a six-position container which will be welded shut once it contains six assemblies that have passed the measurement criteria.

Additional criteria that the assembly must meet prior to being packaged are the heat output and general classification of type. These two requirements insure safe storage of the fuel. The SFCC addresses these items based upon the measured gamma-ray dose of the assembly, which has been shown to be proportional to heat output and a classification of the assembly type based on gamma-ray-to-doubles neutron count rate.

Figure 3 shows the calculated heat to IC value relationship determined from a set of calibration assemblies. For safe packaging, the sum of the measured heat output of the six assemblies going into a container must be below a predetermined value.

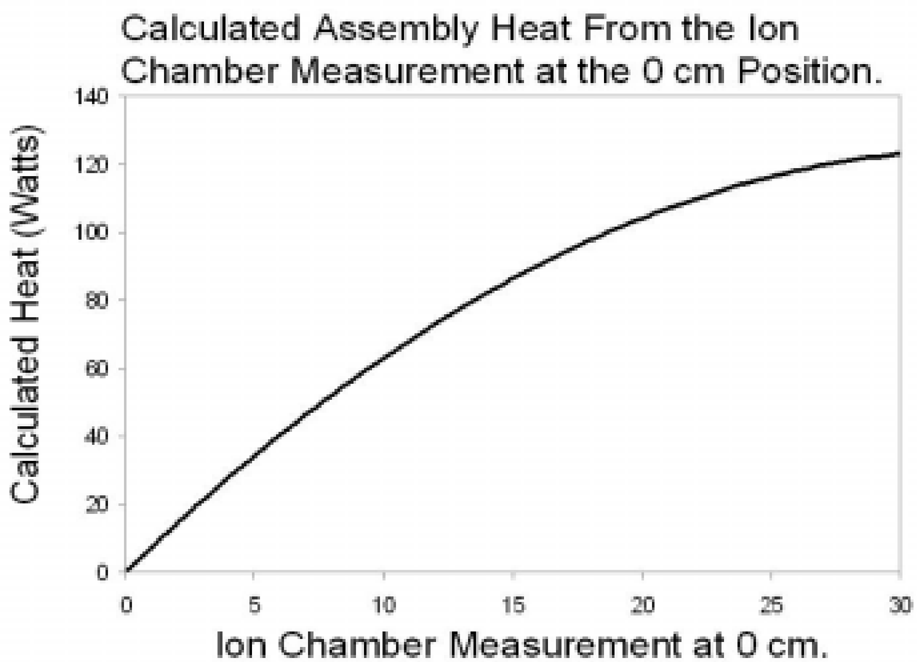

Fig. 3. The relationship of calculated heat to IC measurement for the determination of safe packaging criteria.

Figure 4 shows the map of IC versus neutron doubles measurement values for a classification of the assembly type. There is a resolution method in place to ensure that the assemblies that fall into the indeterminate range can be verified to be of either blanket or driver type assembly to allow the packaging to continue. The majority of assemblies fall into either of the two regions for positive identification based upon the measurement results from the SFCC. Driver assemblies typically fall off the graph scales to the far upper right.

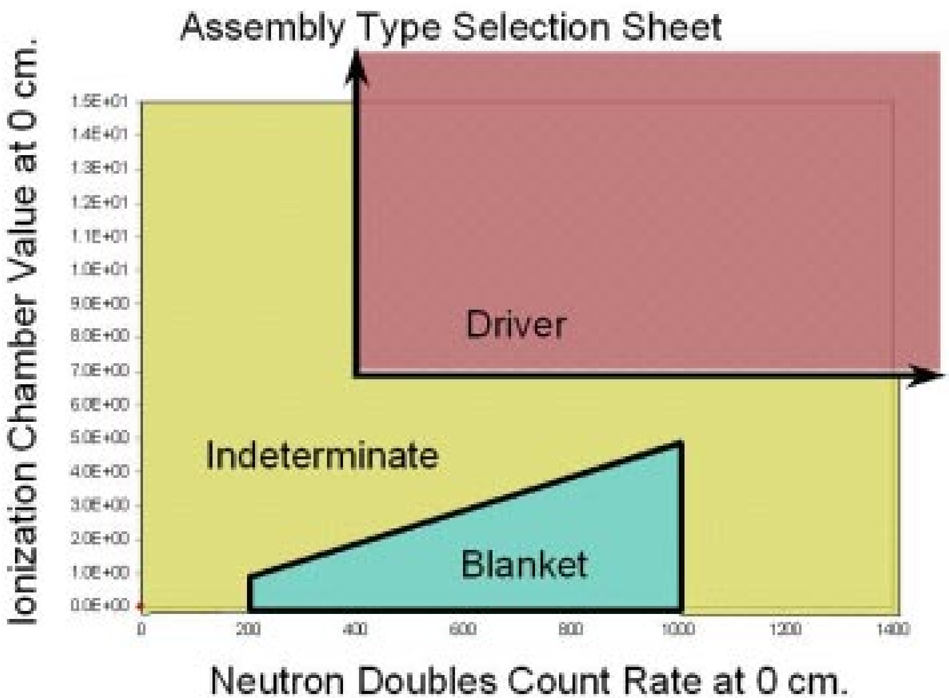

Fig. 4. Relationship of measured IC to neutron doubles count rate for classification of assembly type for the verification of safe packaging criteria.

CONCLUSION

To date, over 1800 assemblies have been processed through the measurement station. The average time for the actual measurement to determine of the plutonium content and criteria for safe packaging is less than 20 min per assembly. The response of the SFCC has been monitored using a reference assembly for the entire period of the campaign. The response of the counter has changed less than 1% over the campaign, which is the level of the uncertainty in the counting statistics for the reference assembly measurements.

REFERENCES

1. "An Underwater Instrument for Breeder Reactor Spent Fuel Assemblies" J.P. Lestone, J.M. Pecos, J.A. Rennie, J.K. Sprinkle, P. Staples, K.N. Grimm, R.N. Hill, I. Cherradi, N. Islam, J.Kulikov and Z. Starovich. Presented at the 21st ESARDA Annual Meeting, Sevilla Spain, May 4-6, 1999, Los Alamos National Laboratory report, LA-UR-99-2000 (1999).